

Final report

“Large-scale Atmospheric Transport Processes” (NAG 5-11285)

9/1/2001 – 8/31/2004

Scientific summary

This research covered a wide range of issues in stratospheric transport.

(i) *The “subtropical edges” of the wintertime midlatitude surf zone*

Continuing earlier work, we continued an investigation of the seasonal behavior of the “edges” of the stratospheric surf zone. These edges form a barrier between the rapidly mixed surf zone and the relatively isolated tropics. In collaboration with Dr Lynn Sparling at GSFC, we used a statistical analysis of HALOE and CLAES trace gas data from UARS to identify and locate these edges during each UARS observing period. We found that the edges on both sides of the equator are present all year (a fact that is important for conceptual models of stratospheric transport), though that on the summer side of the equator is much less sharp than the winter edge. The edges migrate seasonally into the summer hemisphere. Their location also shows influence of the QBO, together with the SAO at higher altitudes. Comparisons with effective diffusivities, and the edge locations, suggest that the edge is sustained by surf zone entrainment during winter, but by the residual circulation during summer. This work is described in Jessica Neu’s Ph. D. thesis, and in Neu et al. (2002).

(ii) *Descent of air within the polar vortex.*

During the SOLVE mission, observations of chemical tracers clearly showed descent of mesospheric air deep into the vortex. Subsequently, we extended the modeling work we had done during the mission to investigate this further. An artificial tracer introduced into the mesosphere in September was found to descend, within the vortex, right down to the lower stratosphere by late winter. The model results clearly showed the mixing of this air with air from lower altitudes; this was evident in modeled tracer correlations. The mixed region, around the vortex edge in the upper stratosphere, expands to fill the entire vortex by the time the air reaches the lower stratosphere. Observed tracer correlations also indicate mixing, but the model mixing appeared to be more vigorous than that implied by the observations. This work is described in Plumb et al. (2003).

(iii) *Theory of tracer-tracer correlations*

The PI has further developed the theoretical basis, and significance, of the spatial distributions of long-lived stratospheric tracers and, particularly, of the tight correlations observed between many such tracers. It has been recognized for about a decade that these correlations are a consequence of the highly anisotropic nature of stratospheric transport (rapid isentropic mixing, slow diabatic advection). However, until a few years ago, the theory had been developed (by the PI and others) only under the unrealistic

assumption that vigorous mixing extends globally, which is at odds with our understanding that the surf zone is confined between the polar vortex and the subtropical "edge." Within this funding cycle, the theory has been extended to allow for interaction between the surf zone and its surroundings of tropical and vortex air (this change introduces major revision to the earlier theory). Nevertheless, the most important conclusions of the earlier theory, such as the ability to deduce net tracer fluxes from the correlation diagram, are recovered in the revised theory. Some preliminary results were presented in Plumb (2002)—a review of stratospheric transport published in the Hirota special issue of *J. Met. Soc. Japan*—and a more complete exposition has recently been submitted to *Rev. Geophys.* (Plumb, 2005).

(iv) *Other relevant activities*

The PI served as Guest Editor of the *J. Atmos. Sci.* special issue on the anomalous southern winter and the dramatic Antarctic major warming event of 2002.

Personnel

Prof. R. Alan Plumb (PI)

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Plumb, R. A.: Stratospheric transport. *J. Met. Soc. Japan*, **80**, 793-809 (2002).

Plumb, R.A., W. Heres, J. L. Neu, N. Mahowald, J. del Corral, G. C. Toon, E. Ray, F. Moore, and A. E. Andrews: Global tracer modeling during SOLVE: high latitude descent and mixing. *J. Geophys. Res.*, **107**, 8309, doi: 10.1029/2001JD001023 (2002).

Neu, J. L., L. C. Sparling, and R. A. Plumb: Variability of the subtropical "edges" in the stratosphere. *J. Geophys. Res.*, **108**, 4482, doi:10.1029/2002JD002706, (2003).

Plumb, R. A.: Tracer-tracer relationships in the stratosphere. Submitted to *Rev. Geophys.*, (2005).